RFAST

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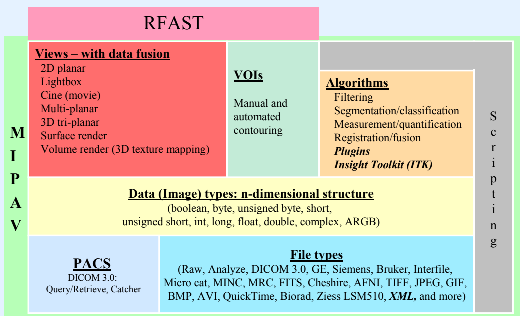
The Radio Frequency Ablation Segmentation Tool (RFAST) is the prototype software application for automatic image registration, segmentation and visualization. Intra-procedural registration and fusion with multimodality images improve the visualization of tumors and thermal lesions in the pre and post RF ablation. Semiautomatic segmentation of the liver, vasculature, and tumor regions are extracted as individual 3D surface meshes and visualized in 3D volume viewer. Building and displaying these objects allows a physician to interactively position the RFA probe to determine an optimal placement relative to other anatomical objects, to more precisely ablate the tumor. Additionally, the multimodality image registration, visualization, and measurement capabilities of RFAST allow a quantitative analysis of post-treatment evaluation.

Radio frequency ablation (RFA) uses high-frequency alternating electrical current to destroy malignant tissue cells by heating them. RFA procedure is done by placing needle-shaped probe into the patient's skin, targeting the tumor location. High-frequency alternating current is applied through the probe's tip, causing the tissue to heat and necrose. The information contained in acquired image volumes of the target area can assist clinicians in diagnosis, procedure planning, and post-treatment monitoring. To improve the probability of success for a RFA treatment, accurate placement and monitoring of the thermal lesions are necessary. Knowledge of the spatial relationship between the neoplastic tissue, organ vasculature and other important structures within the patient's body is intimately linked to success of treatment. Accurate probe placement for sphere-packing with the necessary overlap to ensure the neoplastic tissue and a small margin of normal organ tissue are completely necrosed can be a difficult proposition without proper image guidance and visualization.

The Radio Frequency Ablation Segmentation Tool (RFAST) focuses on assisting clinicians with the planning and evaluation of a RFA procedure performed on malignant tissue within a patient's liver.

Functional Overview

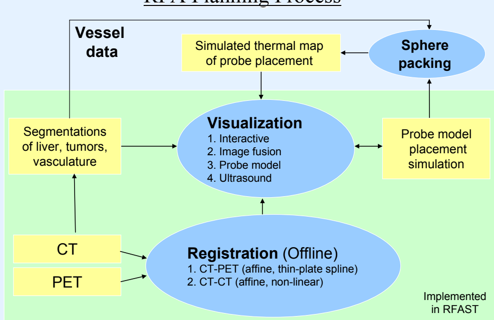


NIH's Medical Image Processing Analysis and Visualization (MIPAV) provide RFAST with a well-featured code base to build upon. MIPAV is already a mature medical imaging project with tools for image processing, segmentation, registration, fusion and visualization already implemented. RFAST reorganizes these tools in a new interface optimized for the specific needs of the RFA planning and evaluation processes. Where functionality was needed that the MIPAV source code could not provide, new generic algorithms (e.g. the Coherence Enhancing Diffusion Filter) and RFA-specific tools (e.g. the ablation simulation and planning facilities) were implemented.

The RFAST process

RFAST provides the user with the tools necessary to isolate the treatment region and optionally register two image data sets. RFAST guides the user through the segmentation of the liver, vasculature, and other important structures, such as a tumor. These segmentations are then extracted as surface meshes and visualized in three-dimensional volume renderer. During the RFA simulation, users interactively position the virtual RFA needle and select the virtual entry and target points with optimal path. Sphere packing simulate the virtual process to ablate the tumors.

RFA Planning Process

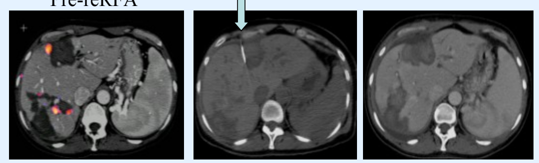


RFAST Registration

RFAST provides for the intra or inter-modal fusion of two image volumes acquired either pre or post operative, and of various modalities, typically Computed Tomography (CT) and Positron Emission Tomography (PET) images. The terminology of registration and fusion often varies. In this work, fusion is defined as the overlay of one image volume onto another one, allowing for blending between the two and independent adjustment of histogram transfer functions and coloring. Registration is the spatial alignment of two image volumes. The CT images of the abdomen provide morphologic information of the liver including its vasculature. PET images provide functional information pertaining to the lesion and are often used to define the target volume. If the volumes are pre-registered (either through a previous registration or a simultaneous acquisition), then fusing images volume data sets can be done by loading a secondary image volume into the first from the RFAST menu. Manual, semi-automatic, and automatic registration methods are implemented in the RFAST application. Automated methods use voxel similarity measures like correlation ratios to determine an optimal registration between two image sets. Manual methods allow physicians to define matching landmarks to register two images.

Through fusing multi-modality image volumes (i.e., CT and PET) clinicians can better visualize the spatial relationship between the tumor and the important morphological features within the patient's body during treatment planning. Registration of morphologic and functional images before, during and after tumor ablation could improve treatment planning, intra-procedural feedback, and assessment of treatment effect. Blending this information may better define the spatial relationship of target lesions and treatment zones, and may facilitate optimal needle placement or repositioning during ablations.

PET and CT fused Pre-reRFA | RFA probe | Post-RFA



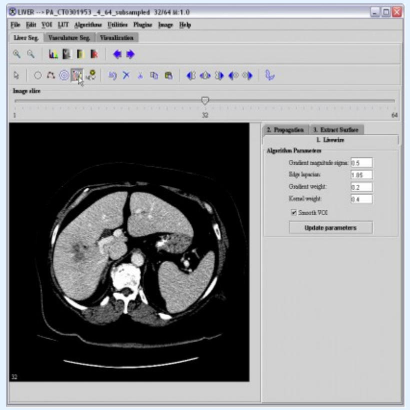
Segmentation

Liver and other structures

To address the complexity of the shape of human organs and the difficulty in the discrimination of all their boundaries from boundaries of adjacent structures in CT volumes, a number of semi-automatic and automatic algorithms are used to define volume of interest contours (VOIs) in the 3D dataset. The livewire paradigm is one method that has proven effective and efficient in the semi-automatic segmentation many of the structures of interest.

An initial VOI of the resampled volume is drawn to define the boundary of the liver in an image plane that bisects the liver using a livewire tool. Once the structure is segmented in one slice, the user can propagate this contour to the adjacent slices in both directions using a combination of a optimization to translate, rotate and scale the VOI to the new slice, and the application of a boundary evolution algorithm to the points of the VOI, to make them better fit the structure in the new slice. Next, we check the image intensities along the new VOI contour and reject it if the intensities have changed too greatly when compared to the previous slice. When this occurs the user can restart the process by performing the livewire segmentation on this new slice and attempting to propagate it up or down in the volume's unsegmented slices. Once this semi-automatic segmentation process is completed, the user can quickly correct the VOI segmentation using a number of manual methods which RFAST shares with MIPAV.

This VOI segmentation process can be repeated to create surfaces of other structures including the tumor in the case of a pre-treatment image, or the ablated area for a post-treatment volume. After the structures are fully segmented, a surface mesh for each structure can be extracted and included for visualization and planning.

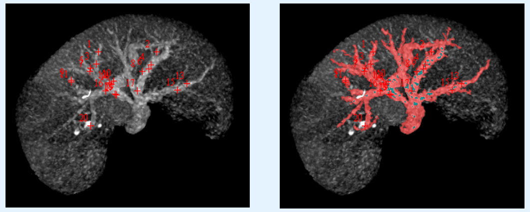


Liver Segmentation

Vasculature

The liver segmentation is used to isolate the liver data from the rest of the image volume. To generate a maximum intensity projection (MIP) which is optimized for segmentation of the liver's vasculature tree, the liver volume is processed with both median and coherence enhancing diffusion filters.

A MIP rendering is generated of the filtered liver volume which elucidates the liver and its internal vascular tree. RFAST searches for points within the MIP which are within the vasculature based on Hounsfield values. These points are displayed to the user directly on the MIP, allowing the user to rapidly select where three-dimensional region growing within the liver volume should begin. These regions are shown as "painted" and can be modified manually by the user to ensure they contain all of the vasculature. This painted region is then converted to a mask image and holes are reduced using a morphological closing operation. Finally, a surface mesh of the vascular tree is extracted from the image mask.



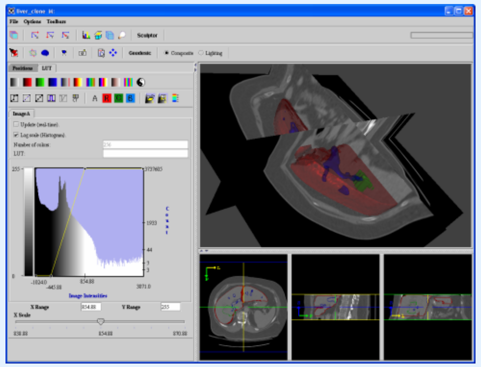
Vasculature Segmentation

Visualization and planning

Once all the necessary surfaces are extracted, the user can visualize the RFA procedure using the multi-planar orthogonal slice view of the image volume and the three dimensional volume rendering. The extracted mesh surfaces are added into these renderings along with models for the RFA probe.

The physical characteristics of the probe, along with its appearance in the visualization are customizable to match the attributes of the wide variety of probe models that are used in ablations. The shape of the ablations generated by each probe can also be altered to match the ablation generated by the real probe.

The probe can be moved in relation to the image volume in many ways: it can be rotated about a target point (the center of the volume or the center of mass of a tumor surface), shifted in any dimension (thereby changing the target point), and moved toward or away from the target point. If these probe movements result in the probe's path intersecting bone or vasculature tissue, the user is visually alerted and shown where the problematic intersection occurs. A similar indicator is shown where the probe path enters the patient's body, allowing the user to better determine the viability of a treatment path. The same entry point can be utilized for multiple ablations – RFAST allows for the probe to be rotated and otherwise moved about its current entry point instead of the target point to more closely simulate the treatment practices of physicians. The complete simulation process begins with the user's movement of the probe to find a viable treatment trajectory. Next, the user simulates a burn in a specific point by moving the probe into the volume and starting the ablation. The ablated region can then be compared with the target region and more ablations can be simulated, if necessary.



Visualization of the segmented liver, vasculature and tumor

Radio Frequency Ablation Registration, Segmentation and Fusion Tool

Surface and volume rendering of the liver, tumor, and vasculature for use in RFA planning